

Integrating Inductive Reasoning to Enhance Conceptual Understanding of Kinematics (Uniform Linear Motion)

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Abstract

This research aims at the effectiveness of inductive reasoning in increasing students' understanding of the concept of Uniform Linear Motion (ULM) by integrating understanding of the philosophy of science as an effort to deepen students' scientific reasoning through the process of direct observation, collecting empirical data, and drawing conclusions independently. The research method used is a quasi-experimental method with a non-equivalent control group design, the research sample consisted of 60 students with a sample of two groups of Motion Physics class students, namely the experimental group taught using an inductive approach, and the control group using conventional deductive-based methods. The results of the descriptive analysis showed that there was an increase in the average post-test score with an increase of 9.97 points. Inferential analysis using the t-test showed $t = 7.07$ with $p < 0.05$, which indicated a significant difference between the two groups. These results strengthen that the inductive approach is more effective in increasing understanding of the uniform linear motion concept. This finding reinforces the effectiveness of the inductive approach, which can serve as a reference in designing more learner-centered instructional strategies.

Keywords: Inductive Reasoning, Philosophy of Science, Kinematics, Uniform Linear Motion.

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1. INTRODUCTION

The teaching and learning process generally still relies on conventional methods, such as lectures and assignments. The learning approach used tends to be teacher-centered (Mudjiarto, 2005). As stated by (Ahzuar & Sabani, 2020), passive learning experiences remain a challenge in Physics education. This highlights the importance of alternative approaches that actively engage students in the process of scientific reasoning. The inductive approach is relevant in this context, as it enables students to construct understanding through observation and drawing conclusions independently. Furthermore (Hidayat & Wulandari, 2020), emphasize the need for alternative learning platforms that go beyond mere content delivery and instead promote student involvement in the process of knowledge construction. The inductive approach aligns with this need by providing space for exploration and scientific reasoning.

Physics is a physical science, which means that studying it requires direct interaction (Handayani et al., 2019). In addition to providing students with scientific knowledge, Physics learning is a process aimed at developing thinking skills and the ability to solve problems in everyday life (Rifky, 2024).

One of the basic physics topics studied in higher education is Kinematics and Dynamics (Nikat et al., 2022). In the Physics course, the concept of motion is one of the essential concepts that students must master (Puspitasari & Febrinita, 2020). The study of kinematics is a part of the Motion Physics course material that examines the phenomena and physical properties of a moving object, regardless of the cause of its motion (Pawestri Primastuti et al., 2023). Kinematics discusses linear motion, which

is divided into two types: Uniform Linear Motion (ULM) and Uniformly Accelerated Linear Motion (UALM) (Ruspitasari et al., 2022). Uniform Linear Motion refers to the motion of an object along a straight path with a constant velocity (v), resulting in zero acceleration (Alhidayatuddiniyah & Astuti, 2020).

In relation to conceptual understanding, Physics material is not merely about delivering concepts; instead, students are encouraged to understand the processes behind phenomena. Students are also expected to think creatively and critically, equipped with scientific process skills, which include both basic and integrated science process skills (Mahmudi & Pramesti, 2017).

Physics learning often focuses on the application of formulas without fostering deep conceptual understanding. It is important to note that students' comprehension of basic physics concepts is categorized into three levels: conceptual understanding, lack of understanding, and misconceptions (Alhidayatuddiniyah, 2023). Misconceptions experienced by students can hinder their ability to grasp the material. Student competence also reflects the achievement of their learning outcomes (Hidayat, Nandang; Susanto, Lufty; Muthoharoh, 2023).

Learning Physics cannot be separated from mastering fundamental Physics concepts through understanding. Physics learning should develop analytical, inductive, and deductive thinking skills in problem-solving. In this context, students are expected to understand Physics concepts ranging from simple to complex (Yulyanti & Pratiwi, 2022).

The inductive reasoning model is defined as a learning plan that proceeds inductively, meaning it draws conclusions based on specific observations (Susanto et al., 2020). The inductive approach provides students with the opportunity to observe motion phenomena and draw conclusions from their observations.

Based on the above, this study aims to evaluate the effectiveness of an inductive reasoning approach in improving students' understanding of Uniform Linear Motion (ULM) by fostering conceptual comprehension and scientific attitudes, and assessing student engagement in the learning process, as well as to evaluate students' responses and engagement in the learning process using the inductive approach. The integration of the philosophy of science is focused on introducing fundamental principles such as observation as the basis of knowledge, the importance of empirical evidence, and the logic of reasoning. Through this approach, students not only understand the concept of Uniform Linear Motion (ULM) mathematically, but also become aware of the scientific process behind the discovery of the concept, thereby fostering scientific attitudes and deeper conceptual understanding.

2. METHODS

This study employs a quasi-experimental method with a non-equivalent control group design. This design was chosen due to contextual constraints, as students were already assigned to fixed classes, preventing randomization. To address this, a pretest was administered to assess baseline equivalence, validated instruments were used, and both groups received instruction under comparable conditions. An independent t-test was conducted to confirm that differences were not caused by external factors.

The learning process under investigation is based on the Motion Physics course syllabus (RPS) for the Informatics Engineering Study Program, as follows:

Table 1. Motion Physics Course Syllabus (RPS)

Week	Expected Learning Outcomes (Sub CP-MK)	Study Materials	Learning Method	Time Allocation	Student Learning Experience	Assessment Criteria, Forms, and Indicators	Weight
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
4 - 5	Students are able to understand and apply the concepts of Kinematics: Uniform Linear Motion (GLB) and Uniformly	Kinematics Concepts: Definitions of motion, distance, speed, and acceleration.	Collaborative Learning	- TM; $2 \times 50 = 100$ minutes - BT; $2 \times 60 = 120$ minutes	- Learn and discuss the concept of GLB and GLBB kinematics. - Explain and apply the	Indicators Ability in: - Understanding the concept of kinematics. - Understanding and explaining Uniform Linear Motion (GLB) and Uniformly Accelerated Linear	16%

Week	Expected Learning Outcomes (Sub CP-MK)	Study Materials	Learning Method	Time Allocation	Student Learning Experience	Assessment Criteria, Forms, and Indicators	Weight
	Accelerated Linear Motion (GLBB) in the horizontal field. • Students are able to apply GLB and GLBB in horizontal motion using Matlab-based applications.	• Uniform Linear Motion (GLB). • Uniformly Accelerated Linear Motion (GLBB) (Horizontal).		• BM; 2×50 = 100 minutes	concept of motion in the horizontal direction.	Motion (GLBB) in the horizontal field, and applying them using <i>Matlab</i> . Criteria: • Accuracy and mastery of the problems. Assessment Forms: • Group presentations • Written test (quiz)	

The following is a research flowchart that outlines the main steps as follows:

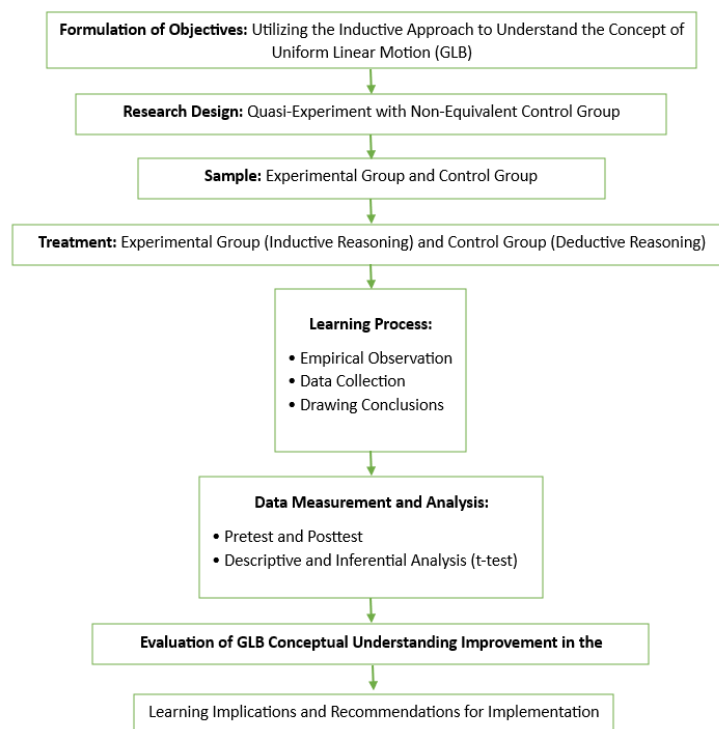


Figure 1. Research Flowchart

1. **Population and Sample**
The population of this study consists of students enrolled in the Motion Physics course, with a research sample of 60 students divided into two groups: an experimental group (30 students) and a control group (30 students).
2. **Learning Design and Treatment**
 - a. **Experimental Group:** Taught using an inductive approach combined with discussions on theories of truth and principles of empiricism from the philosophy of science, followed by discussions where students draw conclusions from their observations, linking these to scientific theories of truth and principles of empiricism.
 - b. **Control Group:** attending traditional lecture-based sessions, where the instructor explains the concept of uniform linear motion (ULM) through direct instruction followed by problem-solving exercises.
3. **Research Instruments**

- a. Conceptual Understanding Test on ULM: An essay test designed to assess students' understanding of the concept of uniform linear motion.
 - b. Attitude Questionnaire: Measures students' attitudes toward the inductive approach and the integration of the philosophy of science.
 - c. Observation: The observation focuses on indicators of student engagement, such as participation, question-asking, and interaction during group discussions.
4. Data Analysis
- a. Descriptive Analysis: Measures the percentage increase in the average score of conceptual understanding of ULM in both the experimental and control groups.
 - b. Inferential Analysis using t-test: Tests the significance of the difference in learning outcomes between the experimental and control groups.

3. RESULT AND DISCUSSION

Based on the objective of this study, which is to evaluate the inductive approach in teaching uniform linear motion (ULM), the research begins with the formulation of the following hypotheses:

- Null Hypothesis (H_0): There is no significant difference in the improvement of ULM conceptual understanding between the experimental group and the control group.
- Alternative Hypothesis (H_1): There is a significant difference in the improvement of ULM conceptual understanding between the experimental group and the control group.

In this context, the experimental group receives instruction through the inductive approach, while the control group is taught using the deductive approach. During the learning process, the experimental group engages in empirical observation, data collection, and drawing conclusions.

Table 2. Quasi-Experimental Research Design

Group	Pre-Test	Treatment	Post-Test
Experimental	y_1	X	y_2
Control	y_1	-	y_2

Next, data collection was carried out. The data collected included pre-test and post-test scores from both the experimental and control groups. The data analysis technique used began with Descriptive Analysis by calculating the mean and standard deviation (SD) of the pre-test and post-test scores.

Mean formula:

$$\bar{X} = \frac{\sum X}{n} \quad \dots (1)$$

Standard deviation formula:

$$SD = \sqrt{\frac{\sum (X - \bar{X})^2}{n - 1}} \quad \dots (2)$$

where: X = Pre-test or post-test score
 n = Number of students in the group

And the results obtained are as follows:

Table 3. Mean and Standard Deviation of Pre-test and Post-test Scores in Each Group

Group	Mean Pre-Test	Mean Post-Test	Standard Deviation Pre-Test	Standard Deviation Post-Test
Experimental	57,2	85,97	5,76	5,65
Control	56,9	76,00	3,83	5,25

These results indicate that both groups had relatively similar pre-test scores. The average pre-test score in the experimental group (57.2) was slightly higher than that of the control group (56.9), suggesting comparable initial understanding. After the learning sessions, the average post-test score in the experimental group (85.96) was higher than that of the control group (76), indicating a greater improvement in understanding the concept of uniform linear motion (ULM) among students in the experimental group.

These results indicate that both groups had comparable initial understanding, which strengthens the validity of the comparison between them. The higher post-test score in the experimental group suggests that the inductive reasoning approach is more effective in improving understanding of the concept of Uniform Linear Motion (ULM), thereby directly addressing the research question.

The mean represents the overall improvement in understanding, while the standard deviation reflects the degree of variation among students within each group.

Next, the difference between the pre-test and post-test means is calculated as follows:

$$\Delta_{Experiment} = \bar{X}_{post_ex} - \bar{X}_{pre_ex} \quad \dots (3)$$

obtained, $\Delta_{Eksperimen} = 28,77$

$$\Delta_{Kontrol} = \bar{X}_{post_kontrol} - \bar{X}_{pre_kontrol} \quad \dots (4)$$

obtained, $\Delta_{Kontrol} = 19,1$

The experimental group experienced an average score increase of 28.77, while the control group showed an increase of 19.1. This improvement indicates that the inductive approach is more effective in enhancing the understanding of the kinematics concept of uniform linear motion (ULM) compared to the deductive or conventional approach.

Hypothesis testing was conducted to determine whether the higher improvement in conceptual understanding in the experimental group was significantly different from that in the control group. This was followed by a t-test to evaluate whether the difference in mean improvement between the experimental and control groups was statistically significant.

$$t = \frac{\bar{X}_{post_Ex} - \bar{X}_{post_control}}{\sqrt{\frac{SD_{Post_Ex}^2}{n_{Post_Ex}} + \frac{SD_{Post_control}^2}{n_{Post_control}}}} \quad \dots (5)$$

Based on the t-test calculation, the result obtained is: $t = 7,07$.

With a degree of freedom ($df = 58$), the calculated t-value is 7.07, and based on SPSS analysis, the p-value obtained is 0.0000000000000347. Since this value is smaller than the critical threshold ($p < 0.05$), the null hypothesis (H_0) is rejected and the alternative hypothesis (H_1) is accepted. This means that the inductive approach integrated with the philosophy of science in the experimental group statistically results in greater improvement in conceptual understanding compared to the conventional approach in the control group.

To strengthen this finding, an effect size calculation using Cohen's d was conducted, where the difference is measured in standard deviation units and yielded a high value. This suggests that the difference between the two groups is not only statistically significant but also has a substantial practical impact on improving the understanding of the concept of Uniform Linear Motion (ULM).

With the acceptance of the alternative hypothesis (H_1), it can be concluded that there is a significant difference in the gain scores between the control and experimental groups. Since the mean gain score of the experimental group is higher than that of the control group, the intervention significantly improved the scores in the experimental group, effectively enhancing the dependent variable, which is the understanding of the kinematics concept of ULM.

The analysis and interpretation of the research findings show the effectiveness of the inductive approach in improving the understanding of uniform linear motion (ULM). The improvement in the

experimental group was centered on a reasoning process that moved from specific cases to general conclusions. Students in the experimental group were given the opportunity to conduct empirical observations and collect data, enabling them to be directly involved in the learning process and further develop their understanding of the kinematics concept through motion observation.

The integration of the philosophy of science through an inductive approach can facilitate students in understanding basic scientific concepts, theories of truth, and the scientific method. Since physics is built upon observation and experimentation, the introduction of these concepts helps students to develop critical thinking, analyze data, and expand their scientific knowledge—specifically, in this context, to better understand the concept of uniformly accelerated linear motion (UALM).

The increased student engagement in the inductive approach is attributed to their active involvement in the learning process, where they do not passively receive information but instead directly observe, explore, and draw conclusions based on empirical data they collect themselves. This process provides space for students to think critically, ask questions, and engage in discussions, thereby fostering curiosity and a sense of responsibility for their learning outcomes.

Below is the result of applying the inductive approach to solving a vertical UALM case:

MAMU: FISTINA OKAN

1. Dik: $v_0 = 10 \text{ m/s}$
 $h_0 = 100 \text{ Meter}$
 $a = 2 \text{ m/s}^2$

Dit: $h = ?$
 $t = ?$

Jawab:

1. $v = v_0 + at$
 $0 = 10 + 2t$
 $t = 2.5 \text{ s}$

2. $h = v_0 t + \frac{1}{2} at^2$
 $h = 10 \cdot 2.5 + \frac{1}{2} \cdot 2 \cdot (2.5)^2$
 $h = 25 + 6.25$
 $h = 31.25 \text{ m}$

3. $h = 100 + 31.25$
 $h = 131.25 \text{ m}$

4. $v = v_0 + at$
 $v = 10 + 2 \cdot 5$
 $v = 20 \text{ m/s}$

5. $t = \frac{v}{a}$
 $t = \frac{20}{2}$
 $t = 10 \text{ s}$

6. $t = 10 - 2.5$
 $t = 7.5 \text{ s}$

7. $h = 100 - 20 \cdot 7.5 + \frac{1}{2} \cdot 2 \cdot (7.5)^2$
 $h = 100 - 150 + 56.25$
 $h = 6.25 \text{ m}$

8. $h = 100 - 6.25$
 $h = 93.75 \text{ m}$

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Figure 2. Results of the Inductive Approach Development in the Experimental Class

This note demonstrates the student's effort in applying the equations of uniformly accelerated motion (UAM) in the context of upward vertical motion, taking into account initial velocity, time, gravity, and displacement. A visual illustration is also included to clarify the understanding of the object's trajectory, along with several corrections that reflect the student's thought process and reflection on the results obtained.

A difference in the improvement of understanding was also found between the inductive and conventional (deductive) approaches. In the control group, students tended to follow a linear thinking pattern—moving from general theory to specific examples—which limited their learning to the passive acceptance of theories without engaging in direct observation.

The following illustrates conventional teaching in the control class:

MAMU: FISTINA OKAN

1. Dik: $v_0 = 10 \text{ m/s}$
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Figure 3. Teaching in the Control Class

The figure represents a structured learning strategy for kinematics: starting from the classification of motion, reinforcement of fundamental formulas, application through example problems, and connection to student exercises. This visual, symbolic, and contextual approach supports students' comprehensive understanding of linear and vertical motion, within the framework of uniform linear motion (ULM), uniformly accelerated motion (UAM), and motion under gravity.

Although there was an improvement in the understanding of the ULM concept in the control group, students were not given the opportunity to construct the concept themselves.

The overall results of this study provide important implications for physics lecturers: through the inductive approach, students are able to understand physics concepts more deeply and actively, which in turn can increase their interest in studying subsequent kinematics topics.

The implementation of the inductive approach contributes positively to curriculum development by promoting a shift from teacher-centered to student-centered learning. This approach allows the curriculum to be designed in a more flexible and contextual manner, emphasizing active learning, problem-solving, and the enhancement of higher-order thinking skills.

4. CONCLUSION

The inductive approach integrated with an understanding of the philosophy of science has proven effective in enhancing students' comprehension of the concept of uniform linear motion. In addition to improving cognitive skills, this approach also fosters students' scientific attitudes in developing a comprehensive understanding of physics. By understanding the scientific foundations and the process of hypothesis testing, students gain a deeper appreciation and understanding of physics.

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